

1 **Claims**

2 What is claimed is:

3 1. A method for transcoding input video data encoded at an initial bit
4 rate into output video data encoded at a target bit rate, the input video data and the
5 output video data comprising one or more of an intra frame (I-frame), a predictive
6 frame (P-frame), and a bidirectional frame (B-frame), the method implemented by
7 a processor, the method comprising:

8 accumulating transcoding error associated with transcoding the input video
9 into the output video data to generate accumulated transcoding error;

10 motion-compensating the accumulated transcoding error to generate
11 motion-compensated accumulated transcoding error;

12 error-compensating the input video data with the motion-compensated
13 accumulated transcoding error to generate error-compensated video data;

14 selectively disabling one or more of the accumulating, motion-
15 compensating, and error-compensating operations in response to detecting one or
16 more conditions related to transcoding the input video data.
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20 2. A method as recited in claim 1 wherein the selectively disabling
21 operation comprises:

22 determining whether the input video data comprises bidirectional frame (B-
23 frame) video data; and
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1 if the input video data comprises B-frame video data,

2 applying a B-frame switching module operable to disable the
3 accumulating, motion-compensating, and error-compensating operations
4 from being applied to the B-frame video data, and

5 inserting B-frame bypass data into the output video data, the B-frame
6 bypass data indicating that the B-frame video data is not transcoded.
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9 3. A method as recited in claim 2 wherein the selectively disabling
10 operation further comprises:

11 determining whether utilization of the processor is greater than a
12 predetermined maximum utilization; and

13 applying the B-frame switching module only if the utilization of the
14 processor is greater than the predetermined maximum and the input video
15 data comprises B-frame video data.
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18 4. A method as recited claim 1 wherein the selectively disabling
19 operation comprises:

20 determining whether the motion-compensated accumulated transcoding
21 error is less than a threshold value; and
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1 if the motion-compensated accumulated transcoding error is less than the
2 threshold value, applying a compensating switching module to prevent the error-
3 compensating operation.

4 5. A method as recited in claim 4 wherein the determining whether the
5 motion-compensated accumulated transcoding error is less than the threshold value
6 comprises calculating an error metric, the error metric being a function of
7 accumulated errors of pixels in a video block.
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10 6. A method as recited in claim 5 wherein calculating the error metric
11 comprises calculating an absolute error of an 8x8 video block according to an
12 equation, the equation being:
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$$14 \quad s = \sum_{i=0}^7 \sum_{j=0}^7 |e(i, j)|,$$

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16 wherein s represents the absolute error, $e(i, j)$ represents accumulated error
17 of each pixel in the 8x8 block, and i and j represent indices to pixels in the 8x8
18 block.
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20 7. A method as recited in claim 4 further comprising setting the
21 threshold value equal to one of a plurality of predetermined threshold values based
22 on one or more of frame-type of the input video data and whether the error-
23 compensating operation is disabled.
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1 8. A method as recited in claim 1 wherein the selectively disabling
2 operation comprises:
3 determining whether the input video data comprises intra-frame (I-frame)
4 video data; and
5 if the input video data comprises I-frame video data, applying a
6 compensating switching module to disable the error-compensating operation.
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9 9. A method as recited in claim 1 wherein the selectively disabling
10 operation comprises applying an open-loop switching module to prevent the
11 accumulating, motion-compensating, and error-compensating operations.
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14 10. A method as recited in claim 1 further comprising determining an
15 initial re-quantization parameter to apply to the error-compensated video data to
16 achieve the target bit rate, the determining comprising applying an equation, the
17 equation being:
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$$19 \quad Q' = \frac{RQ}{R'} ,$$

20 wherein Q' represents the initial re-quantization parameter, R represents the initial
21 bit rate, Q represents a quantization parameter associated with the input video data
22 encoded at the initial bit rate, and R' represents the target bit rate.
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11. A method as recited in claim 10 further comprising determining a secondary re-quantizing parameter according to an equation, the equation being:

$$q_j = \frac{\sqrt[3]{x_j} \times \sum_{n=1}^N \sqrt[3]{x_n^2}}{B'}, n = 1, 2, \dots, N,$$

wherein N represents a number of frames in the input video data, q_j represents the quantization parameter for a j th macroblock in a frame of the input video data, B' represents a target number of bits in a frame of the output video data, n represents the total number of macroblocks in a frame, and x_n represents a complexity of the n th macroblock.

12. A method as recited in claim 11 further comprising calculating the target number of bits, B' , according to an equation, the equation being:

$$B' = \alpha B,$$

wherein α represents a ratio of the target bit rate to the initial bit rate and B represents the number of bits of the current frame in the input video data.

13. A method as recited in claim 11 further comprising calculating the target number of bits, B' , according to an equation, the equation being:

$$B' = w\alpha B,$$

wherein α represents a ratio of the target bit rate to the initial bit rate,
 w represents weighting factor, and B represents the number of bits of the
current frame in the input video data.

14. A method as recited in claim 12 further comprising determining a
difference between the target number of bits and an actual number of bits encoded
in a frame of the output video data, the determining comprising applying an
equation, the equation being:

$$\Delta B = B' - \sum_{n=1}^{j-1} r_n(q_n),$$

wherein ΔB represents the difference between the target number of bits and
the actual number of bits encoded in the frame of output video data, B' represents
the target number of bits, r_n represents the number of bits in an n th macroblock of
the frame, q_n represents the quantization parameter of the n th macroblock of the
frame, j represents a number of macroblocks in the frame, and n is an index
variable that indexes sequentially through the macroblocks in the frame.

15. A method as recited in claim 14 further comprising:
determining whether ΔB is greater than zero; and
if ΔB is greater than zero, recalculating the quantization parameter q_j
according to an equation, the equation being:

$$q_j = \frac{\sqrt[3]{x_j} \times \sum_{n=1}^N \sqrt[3]{x_n^2}}{\Delta B}, n = 1, 2, \dots, N.$$

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2 16. A method as recited in claim 15 further comprising:
3 determining a difference re-quantization parameter, Δq_j , according to an
4 equation, the equation being:

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$$\Delta q_j = q_j - Q'; \text{ and}$$

6 adding Δq_j to Q' to generate a target re-quantization parameter.

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8 17. A method as recited in claim 1 further comprising re-quantizing the
9 error-compensated video data, the re-quantizing comprising looking up a target
10 quantization parameter in a look-up table having a plurality of quantization
11 parameters to achieve the target bit rate.

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14 18. A method as recited in claim 1 wherein the accumulating operation
15 comprises accumulating transcoding error in a frequency domain.
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1 19. A system for transcoding input video data encoded at an initial bit
2 rate into output video data encoded at a target bit rate, the input video data and the
3 output video data comprising one or more of an intra frame (I-frame), a predictive
4 frame (P-frame), and a bidirectional frame (B-frame), the system comprising:

5 an accumulating module accumulating transcoding error associated with
6 transcoding the input video into the output video data to generate accumulated
7 transcoding error;

8 a motion compensation module compensating the accumulated transcoding
9 error with motion estimation data to generate motion-compensated accumulated
10 transcoding error;

11 an error-compensating module compensating the input video data with the
12 motion-compensated accumulated transcoding error to generate error-compensated
13 video data;

14 a re-quantization module controlling a re-quantization level to achieve the
15 target bit rate;

16 a compensation switching module operable to disable the error-
17 compensating module in response to the motion-compensated accumulated
18 transcoding error being less than a threshold value.

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20 20. A system as recited in claim 19 further comprising a B-frame
21 switching module operable to disable the accumulating module and the
22 compensating module if the input video data comprises bidirectional frame (B-
23 frame) video data.
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1 21. A system as recited in claim 19 wherein the quantization parameter
2 control module uses rate information and a quantization parameter in the input
3 video data to determine a re-quantization parameter.

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5 22. A system as recited in claim 21 wherein the re-quantization module
6 comprises a look-up table, the look-up table outputting a re-quantization level and
7 a re-quantization error corresponding to the target bit rate if the input video data
8 comprises a value in a first range.

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10 23. A system as recited in claim 22 wherein the re-quantization module
11 further comprises:

12 a dequantization/quantization path, the dequantization/quantization path
13 used to determine the re-quantization level and the re-quantization error associated
14 with the target bit rate if the input video data comprises a value in a second range;
15 and

16 a level switching module operable to detect the value of the input video data
17 and select the look-up table if the value is in the first range and otherwise select
18 the dequantization/quantization path.

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20 24. A system as recited in claim 22 wherein the look-up table is user-
21 modifiable.

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23 25. A system as recited in claim 23 wherein the first range and the
24 second range are user-selectable.

1 26. A system as recited in claim 23 wherein the re-quantization module
2 further comprises an error calculating module, the error calculating module
3 determining transcoding error as a function of an element in the input video data,
4 an initial quantization parameter associated with the initial bit rate, a target
5 quantization parameter associated with the target bit rate, and a quantization
6 parameter corresponding to the element in the video data.

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8 27. A system as recited in claim 26 wherein the re-quantization module
9 re-quantizes an element of the input video data to a corresponding element of the
10 output video data using an equation, the equation being:

$$X_3 = \frac{X'_3 \times q_m}{16},$$

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13 wherein X_3 represents the corresponding element of the output video data,
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15 X'_3 represents a preliminary re-quantized element obtained from the look-up table
16 based on the element of the input video data, and q_m represents the quantization
17 parameter corresponding to the element in the input video data.
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20 28. A system as recited in claim 26 wherein the error calculating module
21 determines the transcoding error based on an equation, the equation being:

$$X_5 = \frac{X'_5 \times q_m}{16},$$

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23 wherein X_5 represents the transcoding error associated with the element,
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25 X'_5 represents a preliminary re-quantization error obtained from the look-up table

1 based on the element of the input video data, and q_m represents the quantization
2 parameter corresponding to the element in the input video data.

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4 29. A system as recited in claim 19 wherein the input video data
5 comprises video data encoded according to a Motion Picture Experts Group-2
6 (MPEG-2) video format and the output video data comprises video data encoded
7 according to an MPEG-2 format.
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1 30. A system for transcoding video data comprising:
2 input video data encoded at an initial bit rate;
3 means for transcoding the input video data to generate corresponding output
4 video data encoded at a target bit rate, the means for transcoding comprising a re-
5 quantization module including a look-up table having dynamically selectable
6 quantization parameters corresponding to associated bit rates.
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9 31. A system as recited in claim 30 wherein the means for transcoding
10 further comprises an error-compensating module for compensating the input video
11 data with motion-compensated accumulated transcoding error, a motion-
12 compensating module operable to generate the motion-compensated accumulated
13 transcoding error, an accumulating module operable to accumulate transcoding
14 error related to differences between the input video data and the output video data,
15 and one or more switching modules operable to disable one or more of the error-
16 compensating module and the accumulating module.
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1 32. A computer-readable medium having stored thereon computer-
2 executable instructions for causing a processor to perform a method comprising:
3 accumulating transcoding error associated with transcoding input video
4 having an associated initial bit rate into output video data having an associated
5 target bit rate, to generate accumulated transcoding error;
6 motion-compensating the accumulated transcoding error to generate
7 motion-compensated accumulated transcoding error;
8 error-compensating the input video data with the motion-compensated
9 accumulated transcoding error to generate error-compensated video data;
10 selectively disabling one or more of the accumulating and the error-
11 compensating operations in response to detecting one or more conditions related to
12 transcoding the input video data.

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14 33. A computer-readable medium as recited in claim 32, wherein the
15 selectively disabling operation comprises disabling the error-compensating
16 operation if the motion-compensated accumulated transcoding error is less than an
17 error threshold.

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19 34. A computer-readable medium as recited in claim 32, wherein the
20 selectively disabling operation comprises:
21 selecting an error threshold from a plurality of predetermined error
22 thresholds; and
23 disabling the error-compensating operation if the motion-compensated
24 accumulated transcoding error is less than the error threshold.

1 35. A computer-readable medium as recited in claim 32, wherein the
2 selectively disabling operation comprises:
3 determining whether the input video data comprises bidirectional frame (B-
4 frame) video data;
5 determining whether the processor is being utilized at a utilization rate
6 greater than a predetermined utilization rate; and
7 if the input video data comprises B-frame video data and the processor is
8 being utilized at a utilization rate greater than a predetermined utilization rate,
9 disabling the accumulating operation and the error-compensating operation.
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11 36. A computer-readable medium as recited in claim 32, the method
12 further comprising re-quantizing the error-compensated video data using a re-
13 quantization parameter corresponding to the target bit rate.
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15 37. A computer-readable medium as recited in claim 32, the method
16 further comprising:
17 determining a preliminary re-quantization parameter based on a function of
18 the initial bit rate, the target bit rate, and an initial quantization parameter
19 corresponding to the initial bit rate of the input video data;
20 determining a target number of bits in a frame of the output video data, the
21 target number of bits being based on a function of an initial number of bits in a
22 frame of the input video data, the initial bit rate, and the target bit rate;
23 determining a macroblock re-quantization parameter associated with a
24 macroblock in the frame of the output video data, the macroblock re-quantization
25 parameter being determined based on a function of a complexity value associated

1 with the macroblock and the target number of bits in the frame of the output video
2 data;

3 determining a re-quantization difference by subtracting the preliminary
4 quantization parameter from the macroblock re-quantization parameter;

5 adding the re-quantization difference to the preliminary quantization
6 parameter to generate a target re-quantization parameter; and

7 re-quantizing the error-compensated video data using the target re-
8 quantization parameter.

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10 38. A computer-readable medium as recited in claim 37, wherein the
11 determining a target number of bits in a frame of the output video data comprises
12 calculating the target number of bits according to an equation, the equation being:

$$13 \quad B' = (R' / R) \times B,$$

14 wherein B' represents the target number of bits in the frame of the output
15 video data, R' represents the target bit rate, R represents the initial bit rate, and B
16 represents the initial number of bits in the frame of the input video data.

17
18 39. A computer-readable medium as recited in claim 37, wherein the
19 determining a preliminary re-quantization parameter comprises calculating the
20 preliminary re-quantization parameter according to an equation, the equation
21 being:

$$22 \quad Q' = (R' / R) \times Q,$$

23 wherein Q' represents the preliminary re-quantization parameter, R'
24 represents the target bit rate, R represents the initial bit rate, and Q represents the

1 initial quantization parameter associated with the initial bit rate of the input video
2 data.

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4 40. A computer-readable medium as recited in claim 32, wherein the
5 accumulating operation comprises subtracting discrete cosine transform
6 coefficients associated with the output video data from discrete cosine transform
7 coefficients associated with the input video data.